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STANFORD UNIVERSITY SCHOOL OF MEDICINE
STANFORD, CALIFORNIA 94305-5479

Edward H. Shortliffe, MD, PhD
Professor of Medicine and of Computer Science
Associate Dean for Information Resources and Technology
Phone: (650) 725-3385
Fax: (650) 498-4162
Email: ehs@smi.stanford.edu
http://www.smi.stanford.edu/people/ehs

May 18, 1998 (updated May 24, 1999)

Betsy Humphreys, MLS
Deputy Associate Director
Library Operations
National Library of Medicine
8600 Rockville Pike
Bethesda, MD 20894

Dear Betsy:

On behalf of the Principal Investigators for the three InterMed contracts (Contract LM-43512 to Bob Greenes at Brigham and Women's Hospital, Contract LM-43513 to Jim Cimino at Columbia Presbyterian Medical Center, and Contract LM-4314 to myself at Stanford University), plus our co-investigators (Octo Barnett at Massachusetts General Hospital, Stan Huff at the University of Utah, and Vimla Patel at McGill University), I am pleased to send you the final report for our work. We appreciate your willingness to allow us to delay the submission of the report while we have worked to finish papers that summarize the lessons and accomplishments of our 3-year effort. We now have three major papers published or in press with refereed journals, and a fourth about to be submitted. In addition, we have a large number of other publications that we have enclosed to document the results and impact of our work.

Please let us know if we can answer any additional questions. We look forward to continuing to build on the results of our InterMed effort, and hope that our publications will allow others in the medical informatics community to benefit from our experiences and research results.

Sincerely yours,

Edward H. Shortliffe, MD, PhD
Professor of Medicine and of Computer Science

Cc: Milton Corn, MD
Peter Clepper

The InterMed Collaboratory
Final Report
May 1, 1994 – April 30, 1997

Supported by Three Contracts Under the National Library of Medicine's High Performance Computing and Communications (HPCC) Program

Contract LM-43512 to Brigham and Women's Hospital (R.A. Greenes, Principal Investigator)
Subcontract to Massachusetts General Hospital (G.O. Barnett, Co-Investigator)

Contract LM-43513 to Columbia Presbyterian Medical Center
(J.J. Cimino, Principal Investigator)
Subcontract to the University of Utah (S.M. Huff, Co-Investigator)

Contract LM-4314 to Stanford University (E.H. Shortliffe, Principal Investigator)
Subcontract to McGill University (V.L. Patel, Co-Investigator)

We are pleased to submit this final report regarding the above-cited contracts. Although there have been significant challenges associated with this work, and not all original goals were achieved, the overall accomplishments have been numerous and have laid the groundwork for further work that we have proposed to pursue. Enclosed with this report is a summary of all publications related to the InterMed Collaboratory (four journal articles, two refereed conference proceedings, and seven abstracts/demonstrations and technical reports). We have also included a summary of our extensive derivative research that has built on the InterMed experience (13 journal articles, 24 refereed conference proceedings, and 13 abstracts/demonstrations and technical reports). Copies of the individual articles are also provided.

I. Summary of Objectives of the Research

In 1993 we proposed that Columbia University, Harvard University, and Stanford University collaborate by using the national communications network (the Internet) as a means for sharing components and solutions to problems in the application of information technologies for clinical-data and knowledge management. Remarkably, that proposal was written before the World Wide Web had penetrated the research community, so much has changed since our original concepts were delineated. We realized, however, that such a structured collaboration would require that we address the inevitable policy and procedural issues that would arise as our inter-institutional joint projects emerged. Although we originally referred to our collaboration as the "Triad Collaboratory," that name was later changed to the "InterMed Collaboratory" as we sought to make explicit our goal of extending the concepts and tools to a broad audience beyond the three universities that were initially involved. As time went on, we placed special emphasis on evaluating the problems and benefits of such collaboration, seeking and receiving a supplement from the NLM to allow objective outside measurement of our activities by experts on cognitive evaluation from McGill University.

To clarify and focus our activities and goals, we separated our proposed efforts into sets of components that could be constructed at one or more institutions, shared with others, and then

melded to provide applications that could not be developed as effectively by any single group. Although we did not request funding for specific applications, we proposed a variety of *testbed applications,* all of which would depend on contributions from at least two of our institutions and that would build on the shared tools we sought to construct. In particular, we identified a model composed of seven tiers:

Tier 1) Network and Services: The network itself, plus the associated systems methodologies that support use of the network for collaboration

Tier 2) Vocabulary: The taxonomies and vocabularies needed to support components and applications

Tier 3) Knowledge and Data: The databases and knowledge bases on which clinical tools and applications are built

Tier 4) Agents and Components: The agents and components that build on the elements in tiers 1 through 3 and provide the power for modular construction of systems

Tier 5) Development Environments: The application frameworks and authoring or prototyping tools that depend on the components and agents while providing user interfaces for application creation

Tier 6) Testbed Applications: Applications to support clinical care, education, and decision making

Tier 7) Collaborative Policies: The policies, principles, and guidelines (regarding ownership, liability, intellectual property, confidentiality, security, and the like) that must be developed and implemented in defining models by which applications are constructed, and software is shared, across communication networks

We noted that the emergence of advanced networking capabilities under the High Performance Computing and Communications (HPCC) Initiative had made it feasible to consider a new component-based architecture for computer-based applications. We felt that such an architecture would be highly desirable because it would leverage the efforts of multiple participants (potentially at multiple sites), allow reuse of components, foster emergence of standards, permit integration of services from multiple platforms, and provide a mechanism for evolution of the older, more monolithic ("legacy") systems that characterize so much of clinical computing.

We noted, however, that collaboration is often difficult, even within institutions where proximity may not overcome problems with "chemistry" among individuals, competing methodologies, or personality clashes. We accordingly found it appealing to seek collaborations with individuals of like interests and commitment, even if there were a substantial geographic barrier to be overcome. Although the medical informatics community in general, and our three institutions in particular, had not achieved particularly effective inter-institutional collaborations in the past, we were hopeful that a well-motivated, cooperative, and funded effort would help us to overcome those traditional barriers. After all, the Internet itself was a tribute to longstanding dynamic collaborations among systems groups from around the country.

II. Summary of Accomplishments

The work we undertook was more modest than originally proposed due in part to a significant reduction in the funding from what we had requested. However, for purposes of this final report, we will use the Tier-organized original objectives as the basis for summarizing what was accomplished as well as those early goals that we ultimately failed to achieve. The majority of our research results are now available in a large number of publications, copies of which are included with this report. We accordingly provide citations to some of those papers in the summary that follows; details can be found in those references. The InterMed collaborators have coauthored four journal publications (three have appeared or been accepted; the fourth will be submitted within the next several weeks), as well as two extended papers for refereed conference proceedings. Another eight abstracts and technical reports were also produced by the collaborators, many of which led to presentations at national or international meetings.

Equally important, however, is the impact of the InterMed work on other activities in our laboratories and beyond. For example, Jim Cimino built on the Internet and InterMed notions when, as Program Chair, he chose a theme and orientation for the AMIA Fall Symposium in 1996. Furthermore, included with this report are a large number of our papers that, although they do not deal specifically with the InterMed project, draw directly on the InterMed work. In some cases, these papers include authorship by collaborators at two or more of the InterMed sites. These reports include another 13 peer-reviewed journal publications, 23 papers for refereed conference proceedings, and 13 abstract, demonstrations, or other technical publications.

Tier 1 — Network and Services (The network itself, plus the associated systems methodologies that support use of the network for collaboration)

- **Goal:** Our three institutions will work together to establish via the Internet a connectivity that is robust and reliable, and one that promotes open sharing of information and collaboration, but which also facilitates privacy and confidentiality where needed for sensitive information.
  Actual: With the help of the World Wide Web and the further maturing of the Internet's infrastructure, this was clearly achieved.

- **Goal:** We will seek to create a shared architecture for distributed object-oriented software development, including libraries and methodologies based on evolving industry standards.
  Actual: There were modest successes in this area. See, for example, papers D.4, D.6, and D.9.

- **Goal:** We will establish criteria and methods for encryption of sensitive information (patient data as well as other data) and for authenticating user access to the shared servers and components on the network.
  Actual: This was well achieved, in part through our own efforts, but largely because of the further maturation of the Internet and its underlying methods for

data protection, such as is reflected in the current protections for electronic commerce.

- **Goal:** We will assemble and make available to the collaboratory the basic network-based tools and protocols to support interpersonal and intergroup communication and cooperation. These will include those that enable electronic mail with multimedia support, conventions to enable remote workstation display tools, and protocols to support collaborative sketching and authoring tools.
  Actual: We experimented extensively in these areas and learned much about what technologies were most useful to support collaborative activities (see references A.3 and A.4). The Web helped us with multi-media information exchange, which we used extensively for sharing of drawings/diagrams but much less for voice or video exchange.

Tier 2 — Vocabulary (The taxonomies and vocabularies needed to support components and applications)

- **Goal:** We will implement, and mount as a server at Stanford, a shared taxonomy/vocabulary resource suitable to support our diverse applications and databases.
  Actual: Although this was a major activity during the first year of the project, our successes were modest. We have given much thought to why this was difficult, and the problems resulted both from the challenges of building the early collaborative style and substance for InterMed and from the lack of a clear motivating goal for the vocabulary we sought to develop. There is a discussion of these issues in paper A.4.

- **Goal:** A corollary aim is to develop a mechanism for collaborative sharing of controlled medical vocabularies. This will be specifically directed at the successful construction of a vocabulary that facilitates sharing of patient data and medical knowledge across institutions.
  Actual: Problems in this area followed from those mentioned above. Once we began to focus on sharing of clinical guidelines, a much more clearly defined task, the vocabulary issues and the needs for vocabulary sharing became clearer. In retrospect, we should have begun with the guidelines effort.

Tier 3 — Knowledge and Data (The databases and knowledge bases on which clinical tools and applications are built)

- **Goal:** We will share content databases…developed at our various sites. The emphasis will be on making them available by network-based servers, although sharing by direct transfer of databases and knowledge bases among the institutions will also be supported when appropriate.
  Actual: This goal was compromised in part by the reduction in funding, but we did manage to share guidelines and vocabulary among the sites. The former was a particularly important element in the development of GLIF.

- **Goal:** We will expand on already existing on-line information resources … to include a growing collection of vocabulary, treatment guideline and protocol specifications, and knowledge base resources, accessible from graphics-based browsing and retrieval tools.
  Actual: With the help of the Web, this kind of facility was implemented at all of our sites, but the collaboratory did not need to play a major role in making this happen. We did extensively cross-link our web sites, however, which allowed smooth browsing among the InterMed sites.

Tier 4 — Agents and Components (The agents and components that build on the elements in tiers 1 through 3 and provide the power for modular construction of systems)

- **Goal:** We will assemble and make available to the collaboratory a wide set of tools for interpersonal and intergroup communication and cooperation. These will include electronic mail with multimedia support, remote workstation display tools, joint sketching and authoring tools, and information browsing and retrieval tools.
  Actual: We used mailing lists, email, telephone conference calls, one video conference, web pages, Timbuktu (to prepare for demos), and face-to-face meetings to build the collaboration and support our joint activities throughout the InterMed project's activities. See references A.3 and A.4.

- **Goal:** We will modularize and generalize stand-alone network-based information-access tools (e.g., Gopher, WAIS, and WWW), to facilitate their incorporation into horizontally integrated applications to support the healthcare community.
  Actual: This goal did not require extensive work on our part. The greater community pressed ahead in this area, and we used the resulting facilities extensively. All our work presumed an architecture of generalized network-based access tools, and many of the enclosed papers used them to achieve seamless integration of applications across sites.

- **Goal:** We will construct and contribute agents and components that build on the elements outlined above and that provide the power for modular construction of systems.
  Actual: This became a major focus of work. The development and use of GLIF (References A.1 and A.2) was motivated by our goal of creating a network-based set of sharable clinical guidelines.

- **Goals:** We will share means of querying disparate clinical databases (patient data, cleansed of identifiers) in order to accomplish several purposes. Such sharing will allow us to see, for example, whether the data model that has been developed at Columbia-Presbyterian can accommodate the data generated at

another institution (Brigham and Women's Hospital).
Actual: This work was delayed because it was not crucial to the other goals we were pursing in the early years of this project. It again became a pertinent issue when we wrote the follow-on proposal to build a network-based guideline server.

Tier 5 — Development Environments (The application frameworks and authoring or prototyping tools that depend on the components and agents while providing user interfaces for application creation)

- **Goal:** We will adapt PROTÉGÉ, an environment for defining task-specific architectures for purposes of knowledge acquisition in decision-support systems, so that it functions as a network-based application framework for use at all three sites (Stanford)
  Actual: Protégé has been shared and used among the sites, although the web interface that allows it to be used on a Stanford server from a client anywhere on the net is still under development.

- **Goal:** We will provide a sharable application composition framework (initially dubbed "WebWorks") to be built upon the Arachne architecture of Tier 1 and to enable applications to be readily constructed by non-technical individuals from network-based components and resources (Harvard).
  Actual: There has been progress in this area. See References D.6, D.7, and D.9.

- **Goal:** We will adapt Ivory, a system for creating structured clinical progress notes by providers, so that it functions as a server to support the creation of standardized data-entry forms that are individually tailored using a patient's problem list.
  Actual: With the departure of Alex Poon and Keith Campbell from Stanford, and the reduced funding for InterMed, this goal was not pursued.

Tier 6 — Testbed Applications (Applications to support clinical care, education, and decision making)

- **Goal:** We will implement a variety of applications as testbeds….. No financial support is requested for direct development of the testbed applications.
  Actual: Extensive testbed applications were implemented. See the References provided in D, E, and F below.

- **Goal:** To enhance the collaboration, and to investigate emerging technologies for network-based communication, we will experiment with the use of videoconferencing to support collaborative work, both in the form of group videoconferencing from specially set up meeting rooms, and in the form of desktop conferencing tools based on Internet multicast technologies. …. To demonstrate our commitment to the collaboratory concept, we are requesting no funds for travel and will instead rely totally on electronic mail, telephone, and videoconferencing as the basis for our shared activities.

Actual: Our single videoconferencing experiment convinced us that the technology was still too immature and expensive to be used routinely. We found that telephone conferencing worked well once we had met one another face to face, and conference calls became the standard means for non-Internet communications. See References A.3 and A.4 for discussions of these issues.

Tier 7 — Collaborative Policies (The policies, principles, and guidelines (regarding ownership, liability, intellectual property, confidentiality, security, and the like) that must be developed and implemented in defining models by which applications are constructed, and software is shared, across communication networks)

- **Goal:** Fully recognizing the complexity and political barriers implicit in shared development of software components and applications across institutional boundaries, we will explicitly study the policies, principles, and guidelines that need to be developed as our collaborative model is generalized. Issues to be addressed include topics such as intellectual property rights and ownership, Internal Review Board consideration of the use of pooled patient data, confidentiality, security, liability, management of new submissions to the knowledge bases and databases, update/maintenance issues, commercialization of jointly developed components or applications, and the development of metrics of utility.
  Actual: Shortly after our project was funded, the National Research Council began a formal study on patient data privacy and confidentiality in the era of the Internet. Two of our colleagues (Paul Clayton from Columbia and Tom Rindfleisch from Stanford) were members of this panel and played major roles in studying overall issues of data security and privacy. Prof. Clayton chaired the committee. Their efforts allowed them to bring insights and suggestions back to the InterMed collaborators, and the rest of us were involved in assessing how some of the NRC study concepts applied in the setting of Internet-based collaboration, especially when patient data exchange or exposure was potentially involved. InterMed members (Clayton and Rindfleisch) are now viewed as national experts in this general area and have written and spoken extensively on the topic.

Our final specific aim, not mentioned explicitly in the seven-tier model, was the evaluation of our collaborative methodology. The extensive studies by Prof. Patel and her colleagues are the subject of References A.2, A.3, and A.4, as well as several other papers and abstracts that we have submitted with this final report.

Publications from the InterMed Collaboratory
May 1994 – April 1998

The † marks articles for which the final version was previously submitted to NLM. Copies of all other items are included with this report.

Major Articles Focusing Specifically on the InterMed Collaboration

A. Journal Articles:

1. Ohno-Machado L, Gennari JH, Murphy S, Jain NL, Tu SW, Oliver DE, Pattison-Gordon E, Greenes RA, Shortliffe EH, Barnett GO. The GuideLine Interchange Format: A model for representing guidelines. *Journal of the American Medical Informatics Association*, 1998; 5:357-372.

2. Patel VL, Allen VG, Arocha JF, Shortliffe EH. Representing clinical guidelines in GLIF: Individual and collaborative expertise. *Journal of the American Medical Informatics Association*, 1998;5(5):467-83.

3. Patel VL, Kaufman DR, Allen VG, Shortliffe EH, Cimino JJ, Greenes RA. Toward a framework for computer-mediated collaborative design in medical informatics. *Methods of Information in Medicine*, 1999 [in press].

4. Shortliffe EH, Patel VL, Cimino JJ, Barnett GO, Greenes RA. A study of collaboration among medical informatics research laboratories. *Artificial Intelligence in Medicine* 1998;12:97-123.

B. Refereed Conference Proceedings:

1. Shortliffe EH, Barnett GO, Cimino JJ, Greenes RA, Patel VL. InterMed: An Internet-based medical collaboratory. *Proceedings of INET '96* [CD ROM], Montreal, Canada, June 1996.

2. Shortliffe EH, Barnett GO, Cimino JJ, Greenes RA, Huff SM, Patel VL. Collaborative medical informatics research using the Internet and the World Wide Web. In James J. Cimino, Ed., *Proc 1996 AMIA Annual Fall Symposium (formerly SCAMC)*, Washington, DC. October, 1996. Philadelphia: Hanley & Belfus. 1996;125-129.

C. Abstracts and Technical Reports

1. Cimino JJ, Socratous SA, Clayton PD. Automated guidelines implemented via the World Wide Web [abstract]. In Gardner RM, ed.: *Proceedings of the Nineteenth Annual Symposium on Computer Applications in Medical Care*; New Orleans, LA; October-November. Hanley & Belfus, Philadelphia, 1995:941.

2. Oliver DE, Barnes MR, Barnett GO, Chueh HC, Cimino JJ, Clayton PD, Detmer WM, Gennari JH, Greenes RA, Huff SM, Musen MA, Pattison-Gordon E, Shortliffe EH, Socratous SA, Tu SW [demonstration abstract]. InterMed: An Internet-based medical collaboratory. In Gardner RM, ed.: *Proceedings of the Nineteenth Annual Symposium on Computer Applications in Medical Care*; New Orleans, LA; October-November, Hanley & Belfus, Philadelphia, 1995:1023.

3. Oliver DE, Shortliffe EH. Collaborative model development for vocabulary and guidelines [demonstration abstract]. In JJ Cimino, Ed., *Proc 1996 AMIA Annual Fall Symposium (formerly SCAMC)*, Washington, DC. October, 1996. Philadelphia: Hanley & Belfus. 1996;826.

4. †Patel VL, Kaufman DR, Poole E, Shortliffe EH. A cognitive evaluation of the InterMed Collaboratory. Research report submitted to the National Library of Medicine, October 1996.

5. †Patel VL, Arocha JF, Shortliffe EH. Cognitive evaluation guidelines for collaborative research. Research report submitted to the National Library of Medicine, October 1996.

6. Patel VL, Cimino JJ, Shortliffe EH. Explorations in internet-based collaborative informatics research: A cognitive evaluation [abstract]. *Proceedings of the 1996 AMIA Spring Congress*, June, Kansas City, KS.

7. Pattison-Gordon E, Cimino JJ, Hripsak G, Tu SW, Gennari JH, Jain NL, Greenes RA. Requirements of a sharable guideline representation for computer applications. Technical report, 1996.

Derivative Articles From the InterMed Laboratories that Drew Directly on the Work Supported by the NLM's InterMed Contract

D. Journal Articles:

1. Campbell KE, Oliver DE, and Shortliffe EH. The Unified Medical Language System: Toward a collaborative approach for solving terminologic problems. *Journal of the American Medical Informatics Association* 1998;5:12-16.

2. Cimino JJ. Use of the Unified Medical Language System in patient care. *Methods of Information in Medicine*; 1995;34(1/2):158-164.

3. Cimino JJ, Socratous SA, Clayton PD. Internet as clinical information system: Application development using the World Wide Web. *Journal of the American Medical Informatics Association*; 1995;2(5):273-284.

4. Cimino JJ. Formal descriptions and adaptive mechanisms for changes in controlled medical vocabularies. *Methods of Information in Medicine*. 1996;35(3):202-210.

5. Cimino JJ. Distributed cognition and knowledge-based controlled medical terminologies. *Artificial Intelligence in Medicine*; 1998;12(2):155-170.

6. Deibel SRA, Greenes RA. An infrastructure for the development of health care information systems from distributed components. *J Amer Soc for Info Sci*, 1995; 46(10):765-771.

7. Deibel SRA, Greenes RA. Radiology systems architecture. In Greenes RA, Bauman RA (eds.) Imaging and Information Management: Computer Systems for a Changing Health Care Environment. *Rad Clinics of N Amer*. Philadelphia: W.B. Saunders. 1996;34(3):681-696

8. Detmer WM, Shortliffe, EH. Using the Internet to improve knowledge diffusion in medicine. *Communications of the ACM*, 1997;40(8):101-108.

9. Greenes RA, Deibel SRA. Constructing workstation applications: Component integration strategies for a changing health-care system. In *IMIA Yearbook of Medical Informatics 96*: (Van Bemmel JH, McCray AT, eds). Rotterdam, The Netherlands: IMIA. 1996; 76-86

10. Musen, MA. Tu, SW, Das, AK., Shahar, Y. (1996). EON: A component-based approach to automation of protocol-directed therapy. *Journal of the American Medical Informatics Association*; 1996;3:367-388.

11. Parker JA, Wallis JW, Halama JR, Brown CV, Cradduck TD, Graham MM, Wu E, Wagenaar J, Mammone GL, Greenes RA, Holman BL. Collaboration using Internet: Development of case-based teaching files (Report of the Computer and Instrumentation Council Internet Focus Group). *J Nucl Med* 1996;37(1):178-184.

12. Patel VL. Individual to collaborative cognition: A paradigm shift? *Artificial Intelligence in Medicine* 1998;12(2):93-96.

13. Patel VL, Cytryn KN, Jones PC, Safran, C. The changing face of the clinical encounter with the collaborative health care team. Submitted to *Teaching and Learning in Medicine*, May 1999.

E. Refereed Conference Proceedings:

1. Barnes M, Barnett GO. An architecture for a distributed guideline server. In Gardner RM, ed.: *Proceedings of the Nineteenth Annual Symposium on Computer Applications in Medical Care*; New Orleans, LA; October-November, Hanley & Belfus, Philadelphia, 1995;233-237.

2. Cimino JJ, Socratous SA, Grewal R. The informatics superhighway: Prototyping on the World Wide Web. In Gardner RM, ed.: *Proceedings of the Nineteenth Annual Symposium on Computer Applications in Medical Care*; New Orleans, LA; October-November, Hanley & Belfus, Philadelphia, 1995:111-115.

3. Cimino JJ, Socratous S. Just tell me what you want!: The promise and perils of rapid prototyping with the World Wide Web. In Cimino JJ, ed.: *Proceedings of the American Medical Informatics Association Annual Fall Symposium (formerly SCAMC)*; Washington, DC; October, Hanley & Belfus, Philadelphia, 1996:719-723.

4. Cimino JJ, Elhanan G, Zeng Q. Supporting infobuttons with terminological knowledge. *Proceedings of the 1997 AMIA Annual Fall Symposium*, Nashville, Tennessee. Philadelphia: Hanley&Belfus, 1997;528-532.

5. Detmer WM, Shortliffe EH. A model of clinical query management that supports integration of biomedical information over the World Wide Web. In Gardner RM, ed.: *Proceedings of the Nineteenth Annual Symposium on Computer Applications in Medical Care*; New Orleans, LA; October-November, Hanley & Belfus, Philadelphia, 1995;898-902.

6. Elhanan G, Socratous SA, Cimino JJ. Integrating DXplain into a Clinical Information System using the World Wide Web. In Cimino JJ, ed.: *Proceedings of the American Medical Informatics Association Annual Fall Symposium (formerly SCAMC)*; Washington, DC; October, Hanley & Belfus, Philadelphia, 1996:348-352.

7. Elhanan G, Cimino JJ. Controlled vocabulary and design of laboratory results displays. *Proceedings of the 1997 AMIA Annual Fall Symposium*, Nashville, Tennessee. Philadelphia: Hanley&Belfus, 1997;729-723.

8. Fridsma DB, Gennari JH, Musen MA. Making generic guidelines site-specific. In J.J. Cimino, Ed., *Proceedings 1996 AMIA Fall Symposium*, Philadelphia: Hanley & Belfus, 1996:597-601..

9. Gennari JH, Oliver DE, Pratt W, Rice J, Musen MA. A Web-based architecture for a medical vocabulary server. *Proceedings Nineteenth Annual Symposium on Computer Applications in Medical Care*, New Orleans, LA, 1995;275-279.

10. Greenes RA, Deibel SRA. Collaborative health-care information system development through sharable infrastructure, services, and paradigms. *Proceedings of MEDINFO 95*. International Medical Informatics Association, 1995;190-194.

11. Karson TH, Perkins C, Dixon C, Ehresman JP, Mammone GL, Sato L, Schaffer JL, Greenes RA. The PartnerWeb Project: A component-based approach to enterprise-wide information integration and dissemination. *Proc 1997 AMIA Annual Fall Symposium (formerly SCAMC)*, Nashville, TN, October, 1997. Philadelphia: Hanley & Belfus. 1997; 359-363

12. Kohane IS, van Wingerde FJ, Fackler JC, Cimino C, Kilbridge P, Murphy S, Chueh H, Rind D, Safran C, Barnett GO, Szolovits P. Sharing electronic medical records across multiple heterogeneous and competing institutions. *Proc of the 1996 AMIA Annual Fall Symposium*, 1996,608-612.

13. Liem EB, Obeid JS, Shareck P, Sato L, Greenes RA. Representation of clinical practice guidelines through an interactive WWW interface. P*roc Nineteenth Annual Symposium on Computer Applications in Medical Care (SCAMC)*, New Orleans, LA. Nov, 94. Philadelphia: Hanley & Belfus. 1995;223-27

14. McHolm G, Obeid J, Karson TH, Sato L, Schaffer JL, Greenes RA. Facilitating physician referrals on the World Wide Web: Representation and appropriate utilization of clinical expertise. *Proc 1996 AMIA Annual Fall Symposium (formerly SCAMC)*, Washington, DC. October, 1996. Philadelphia: Hanley & Belfus. 1996;724-728

15. Murphy SN, Barnett GO. Achieving automated narrative text interpretation using phrases in the electronic medical record. *Proceedings of the 1996 AMIA Annual Fall Symposium*, 1996;532-536.

16. Pattison-Gordon E, Greenes RA. An empirical investigation into the conceptual structure of chest radiograph findings. *Proceedings of the Eighteenth Annual Symposium on Computer Applications in Medical Care*, Washington, DC. Nov, 94. New York: Hanley & Belfus, Philadelphia, 1994;257-261.

17. Shareck EP, Greenes RA. Publishing biomedical journals on the World-Wide Web using an open architecture model. *Proc 1996 AMIA Annual Fall Symposium (formerly SCAMC)*, Washington, DC. October, 1996. Philadelphia: Hanley & Belfus. 1996;343-347.

18. Sherman, EH, Hripcsak, G, Starren, J, Jenders, RA, Clayton, P. Using intermediate states to improve the ability of the Arden Syntax to implement care plans and reuse knowledge. *J Am Med Informatics Assoc*; 2 (Suppl.): 1995;238-42.

19. Sujansky W, Altman RB. An evaluation of the transfer model for sharing clinical decision-support applications. In JJ Cimino, Ed., *Proceedings of the AMIA Annual Fall Symposium*, Washington, D.C. Philadelphia: Hanley & Belfus, 1996;468-472.

20. Tu SW, Musen MA. The EON model of intervention protocols and guidelines. In JJ Cimino, (ed.) *Proc of the 1996 AMIA Annual Fall Symposium*, 1996;587-591.

21. van Wingerde FJ, Schindler J, Kilbridge P, Szolovits P, Safran C, Rind D, Murphy S, Barnett GO, Kohane IS. Using HL7 and the World Wide Web for unifying patient data from remote databases. *Proc of the 1996 AMIA Annual Fall Symposium*, 1996;643-647.

22. Zeng Q, Cimino JJ. Mapping medical vocabularies to the Unified Medical Language System. In JJ Cimino, ed.: *Proceedings of the American Medical Informatics Association Annual Fall Symposium (formerly SCAMC)*; Washington, DC; October, Hanley & Belfus, Philadelphia, 1996:105-109.

23. Zeng Q, Cimino JJ. Linking a clinical system to heterogeneous information resources. *Proceedings of the 1997 AMIA Annual Fall Symposium*, Nashville, Tennessee. Philadelphia: Hanley&Belfus, 1997;553-7.

F. Abstracts, Editorial, Technical Reports, and Other Miscellaneous Publications

1. Barnett GO, Shortliffe EH, Chueh H, Piggins J, Greenes R, et al. Patient care applications on the Internet [demonstration abstract]. *Proc Eighteenth Annual Symposium on Computer Applications in Medical Care (SCAMC)*, Washington, DC. Nov, 94. Philadelphia: Hanley & Belfus. 1994;1060

2. Cimino JJ. Controlled vocabularies for capturing clinical encounters [abstract]. In: Hripcsak G, ed. *Proceedings of the 1994 Spring Congress of the American Medical Informatics Association*; Boston, MA; May, 1995:72.

3. Cimino JJ, Zeng Q, Elhanan G, Socratous SA. From coded patient data to World Wide Web information via the UMLS [abstract]. In: Humphreys BL, ed. *Proceedings of the 1996 Spring Congress of the American Medical Informatics Association*; Kansas City, MO; June, 1996:92.

4. Greenes RA. The next generation. H*arvard Med Alumni Bull* 1996;69(4):14-19

5. Greenes RA. Information technology in a time of change (editorial). *Radiographics* 1996;16(3):692

6. Labkoff SE, Daily JP, Karson T, Schaffer J, Sato L, McHolm G, Obeid J, Shareck P, Greenes RA. Health care enterprise integration tools using a WWW platform: Application in an infectious disease service [demonstration abstract]. *Proc 1996 AMIA Annual Fall Symposium (formerly SCAMC)*, Washington, DC. October, 1996. Philadelphia: Hanley & Belfus. 1996; 942

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